

**REMARKS**

This is a full and timely response to the Office Action mailed September 25, 2003.

By this Amendment, claims 1 and 5 have been amended to overcome the rejection under 35 USC §112, second paragraph. Support for claim amendments can be found variously throughout the specification, for example, page 4, line 3 and page 5, line 15. Claims 1-10 are pending in this application.

In view of this Amendment, Applicant believes that all pending claims are in condition for allowance. Reexamination and reconsideration in light of the above amendments and the following remarks is respectfully requested.

**Claim of Priority**

Applicant notes that the Examiner has failed to acknowledge Applicant's claim for foreign priority under 35 U.S.C. §119 and that the certified copy of the priority document has been received. Applicant respectfully requests such acknowledgement in the next Official Action.

**Rejection under 35 U.S.C. §112**

Claims 1-10 are rejected under 35 U.S.C. §112, second paragraph, for alleged indefiniteness. Applicant respectfully traverses this rejection.

However, in order to expedite prosecution, Applicant has amended claims 1 and 5 to address the Examiner's concerns. Thus, withdrawal of this rejection is respectfully requested.

**Rejections under 35 U.S.C. §103**

Claims 1-4 are rejected under 35 U.S.C. §103(a) as being unpatentable over Hiramatsu et al. (hereinafter "Hiramatsu"). Applicant respectfully traverses this rejection.

Under U.S. practice, to establish a *prima facie* case of obviousness, three basic criteria must be met. First, there must be some suggestion or motivation, either in the references themselves or in the knowledge generally available to one of ordinary skill in the art, to modify the reference or to combine reference teachings. Second, there must be a reasonable expectation of success. Finally, the prior art reference (or references when combined) must teach or suggest all the claim limitations. Here, in this case, none of these criterias have been met.

The present invention is directed to a method of forming a substrate made of a Group III-V nitride compound. The Group III-V includes at least one element from Group IIIB elements and at least nitrogen (N) from Group VB elements. The claims require that the substrate be grown on a growth base with a thickness of smaller than or equal to 100 $\mu\text{m}$ , and the substrate have a thickness of larger than or equal to 200 $\mu\text{m}$  and a curvature smaller than or equal to 0.03 $\text{cm}^{-1}$ . The curvature of the substrate is caused by a difference in thermal expansion coefficients of the growth base and the substrate.

In contrast, Hiramatsu discloses a sapphire substrate (i.e. “growth base”) having a thickness of 250 $\mu\text{m}$  which is much larger than that recited in the claims (“a growth base with a thickness of smaller than or equal to 100 $\mu\text{m}$ ”).

In addition, Hiramatsu fails to disclose the specific limitation of “a curvature smaller than or equal to 0.03 $\text{cm}^{-1}$ ”. As discussed on pages 12-13 of the specification, experiments were carried out to show the relationship between the thickness  $t_2$  of the GaN substrate 12 and the curvature  $K$  of the substrate 12 (see Figures 6 and 7 (Fig. 7 shows a part of Fig. 6 enlarged)) when values in Table 1 below were assigned to the parameters in the numerical expression 1 (see page 7) and the thickness  $t_1$  of the growth base 11 made of sapphire was varied.

$T_g - T_r$	1015°C
$\alpha_1$	$7.50 * 10^{-6} \text{ } ^\circ\text{C}^{-1}$
$\alpha_2$	$5.45 * 10^{-6} \text{ } ^\circ\text{C}^{-1}$
$E_1$	$345.0 * 10^9 \text{ Pa}$
$E_2$	$126.0 * 10^9 \text{ Pa}$
$\rho_1$	0.33
$\rho_2$	0.33

Table 1

In accordance with the calculation model shown in Figure 6, the GaN substrates 12 with various thicknesses were grown by means of the HVPD over the growth bases 11 made of sapphire with various thicknesses, and the curvature thereof was obtained by measuring their reflecting angles. From these experiments, it was confirmed that the relationship between the thickness  $t_1$  of the growth base 11, the thickness  $t_2$  of the substrate 12 and the curvature  $K$ , which were obtained with the actual measurement, greatly conformed to the calculation model shown in Figure 6. As shown in Figure 7, the curvature, 0.03  $\text{cm}^{-1}$ , was the critical point for causing crack and, when the curvature  $K$  of the substrate 12 was smaller than or equal to 0.03 $\text{cm}^{-1}$ , no

crack occurred in the substrate 12. This important characteristic is not at all taught or suggested in Hiramatsu.

Thus, since Hiramatsu fails to teach or suggest the noted claim limitations, a *prima facie* case of obviousness cannot be established.

It is the Examiner's position that the exact thickness of the growth base and substrate, and the exact curvature of the substrate would have been well within the skill level of the art as long as the thickness of the substrate exceeds the critical thickness so that the strain in the substrate is reduced and the substrate does not suffer from cracks. However, Applicant disagrees with the Examiner in this regard.

In the reference, Hiramatsu discusses the strain of the grown GaN (thickness from 11 $\mu$ m to 1200 $\mu$ m) on sapphire substrate having a thickness of 250 $\mu$ m. The GaN layer grown on the 250 $\mu$ m sapphire substrate has many cracks as explained in the reference in correspondence with that shown in Figures 2, 7 and 8. Although Hiramatsu discusses a strained GaN layer having no cracks, Hiramatsu discloses that the theoretical data about cracks in the GaN layer does not agree or correspond with the experimental data (see page 1532, left column, lines 13-18 and Figure 7). In other words, since the strain in the GaN layer should be almost completely relaxed at a thickness greater than 100 $\mu$ m, there should be no cracks in a GaN layer having a thickness of greater than 100 $\mu$ m. However, such a result is not shown in Figure 7.

Figure 7 shows the strain versus *thickness of GaN* with cracks and without cracks. In Hiramatsu's experimental results, all data points are for GaN layers with cracks. These data points show that cracks are formed even in GaN layers having a thickness of greater than 100 $\mu$ m. Hiramatsu did not obtain a GaN layer without cracks because its sapphire substrate is too thick (250 $\mu$ m). Cracks are formed in a step of decreasing substrate temperature after growth at high temperature. During the step of decreasing substrate temperature, many cracks are generated at the interface between the grown GaN layer and the substrates because there is a difference of thermal expansion between the sapphire substrate and GaN layer.

The present invention has discovered that when the exact thickness of substrates (i.e. "growth base" in the present claims) is bigger than 100 $\mu$ m, some cracks are generated at the interface between the grown layer ("substrate in the present claims") and the substrate (i.e. "growth base" in the present claims) because the substrate is too rigid (caused by the substrate being too thick). Such a teaching is not at all disclosed or suggested in Hiramatsu.

Hiramatsu focuses on the thickness of the GaN layer and teaches that as long as such thickness exceeds the critical thickness so that the strain in the growth layer is reduced, a GaN layer free from cracks can be obtained.

In contrast, the present invention focuses on the relationship between the thickness of the GaN layer and the growth base layer, and the curvature of the GaN layer. As stated on page 7 and 8 of the specification, due to the difference in thermal expansion coefficients of the substrate (i.e. GaN layer) and the growth base, warping occurs through cooling after growing the substrate. By making the thickness of the growth base smaller than or equal to 100 $\mu$ m and the thickness of the substrate larger than or equal to 200  $\mu$ m, stress caused by the warping is concentrated in the growth base, and thus, cracks occur exclusively in the growth base. Further, the thickness of the substrate relative to the growth base is adjusted so that the curvature K of the substrate is smaller than or equal to 0.03cm<sup>-1</sup>, and thus, the substrate is free from cracks. Thus, if the thickness of the GaN layer and the growth base layer, and the curvature of the GaN layer satisfy the values set forth in the claims, a GaN layer free from cracks can be obtained.

In addition, as discussed on page 10 of the specification, after the substrate is formed and the growth base is removed, the warping of the substrate is eliminated and the substrate becomes flattened. Since the growth base is thin, less than or equal to 100 $\mu$ m, the growth base is easily removed thereby eliminating the occurrence of crack due to application of stress on the substrate during the removal step. Further, when crack occurs in the growth base as above, removal of the growth base can be performed even easier. Such an advantage is not at all disclosed in Hiramatsu since the reference focuses on the thickness of the GaN layer and not the sapphire base.

Since Hiramatsu focuses on only one aspect of the claimed invention, i.e. thickness of the GaN layer, its teaching and suggestions would not have motivated one skilled in the art to modify the base layer to be thinner or even contemplate the necessary curvature of the substrate to prevent cracking. Also, given the contradictory results in Hiramatsu, one skilled in the art would not have a reasonable expectation of success if such modification to arrive at the present invention is made.

Thus, for these reasons, withdrawal of this rejection is respectfully requested.

As set forth in items 3 and 4 of the action, claims 5-10 are rejected under 35 U.S.C. §103(a) as being obvious over Hiramatsu et al. in view of Chen et al. or JP 10-256,662. Applicant respectfully traverses these rejections for the same reasons as noted above. Since Chen et al. or JP 10-256,662 fails to cure the deficiencies in Hiramatsu et al. outlined above, a *prima facie* case of obviousness cannot be made based on the combination of these references. Thus, withdrawal of this rejection is respectfully requested.

**CONCLUSION**

For the foregoing reasons, all the claims now pending in the present application are believed to be clearly patentable over the outstanding rejections. Accordingly, favorable reconsideration of the claims in light of the above remarks is courteously solicited. If the Examiner has any comments or suggestions that could place this application in even better form, the Examiner is requested to telephone the undersigned attorney at the below-listed number.

Dated:

Respectfully submitted,

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